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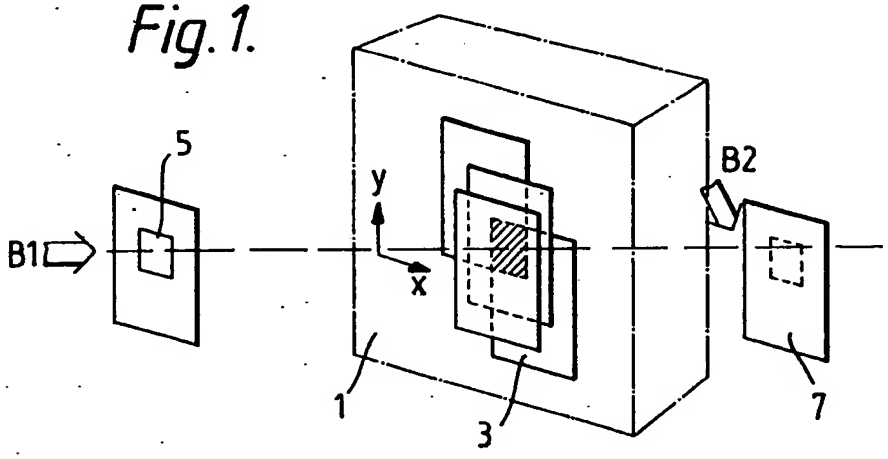
(54) Secure holographic data storage using an optical phase encryption device

(57) A system for securely storing information carried on a document comprises an optical phase encryption device 1 consisting of parallel identical plates 3. Each plate is divided into an array of pixels and is holographically recorded with a spatial pattern of phase retardations, so that each pixel exhibits a predetermined phase retardation. The plates are spaced apart along an optical axis and are displaced relative to each other along x and y axes perpendicular to the optical axis. The information to be stored is represented on a transparency 5 through which a coherent light beam B1 from a laser is passed. An image of the information is thereby projected through the overlapping region of the plates, and the light emerging from the encryption device is phase-changed by the plates. A second coherent beam B2 is used to record the resultant phase-scrambled image holographically on a photographic plate 7. To retrieve the information, a phase conjugate of the phase-scrambled image is passed through the phase encryption device 1 and the resultant unscrambled image is displayed on a screen (15, Fig. 2).

Fig. 1.



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The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

Fig.1.

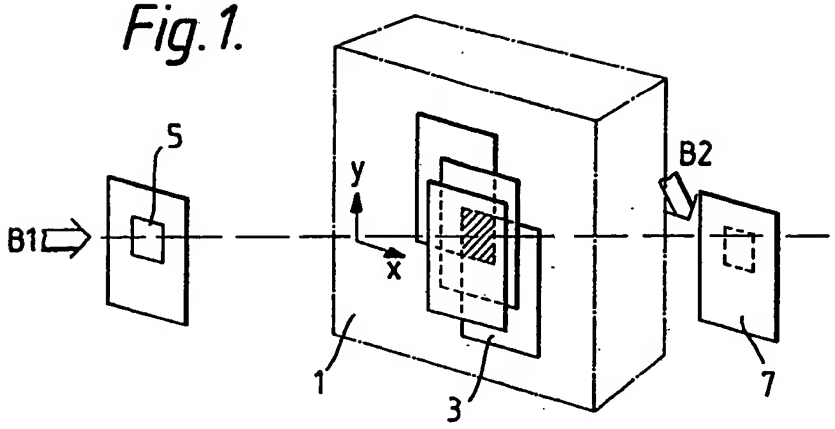


Fig.2.

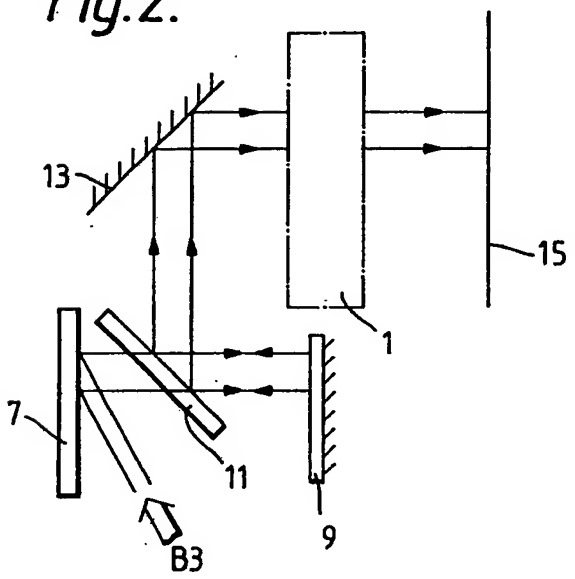
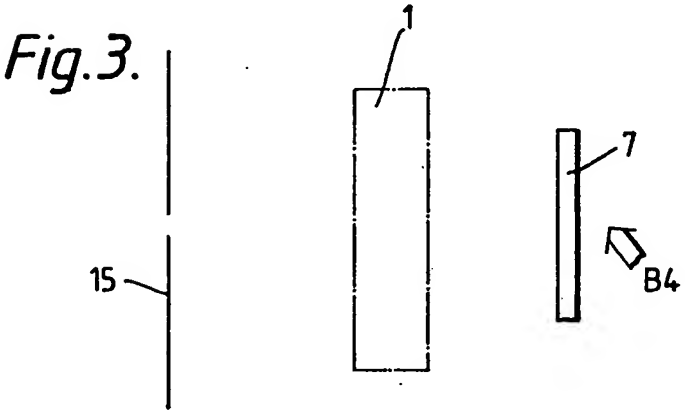


Fig.3.



SPECIFICATION

Secure storage system

This invention relates to secure storage systems. In particular the invention relates to secure storage systems for the storage of information carried on a document.

Such systems may be used, for example, for the storage of classified information, and generally comprise means for storing the information in an encrypted form, such that an unauthorised person is unable to decrypt the information, the information being subsequently decrypted by an authorised person in possession of means for performing this decryption.

It is an object of the invention to provide such a secure storage system for storing information carried on a document.

According to a first aspect of the present invention a secure storage system for the storage of information carried on a document comprises: means for directing light from an input image representative of the document through a first optical arrangement effective to produce a modified image across which there is a spatial pattern of phase variations relative to said input image; means for holographically recording the modified image; and means for subsequently directing light from the modified image through a second optical arrangement effective to reproduce the input image.

The second optical arrangement suitably includes means for forming the phase conjugate of the modified image. In such a system the second optical arrangement may include the first optical arrangement, light from the phase conjugate of the modified image being directed through the first optical arrangement.

The first optical arrangement suitably comprises at least one recording of a spatial pattern of phase variations. The input image may be smaller than the corresponding area of the first optical arrangement such that the portion of the first optical arrangement through which light from the input image passes determines the form of the modified image. Where the first optical arrangement includes more than one recording, these will be arranged in series. In such a case the recordings may be arranged to be displaceable relative to each other in the directions normal to the direction of propagation of the light from the image, so as to vary the portions of the recordings through which light from the input image passes, and thereby vary the form of the modified image.

According to a second aspect of the present invention a secure storage method for the storage of information carried on a document comprises: directing light from an input image representative of the document through a first optical arrangement effective to produce a modified image across which there is a spatial pattern of phase variations relative to said input image; holographically recording the modified image; and subsequently directing light from the modified image through a second optical arrangement effective to reproduce the input image.

Two secure storage systems carried on a document in accordance with the invention together with methods of using the systems will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of the first system being used to record information to be stored;

Figure 2 is a schematic diagram of the first system being used to reproduce an image of the information previously stored; and

Figure 3 is a schematic diagram of the second system being used to reproduce an image of the information previously stored.

Referring firstly to Fig. 1, the first system to be described includes an optical phase encryption device 1 comprising four identical plates 3. Each plate is divided into an array of pixels, the plate being holographically recorded with a spatial pattern of phase retardations, each pixel thus exhibiting a predetermined phase retardation. The plates 3 are arranged in a spaced parallel configuration along an optical axis, each plate being displaced along the two orthogonal directions x and y perpendicular to the optical axis by a chosen amount. Also arranged along the optical axis are a transparency 5 representing the information on a document which it is required to store, and a photographic plate 7 carrying a photosensitive layer.

To store the information carried on the transparency 5, a coherent light beam B1 from a laser (not shown) is shone through the transparency 5 so as to project an image of the information through the region shown shaded in the figure which represents the area normal to the beam B1 where the plates 3 overlap. As the light from the transparency 5 passes through the plates 3, its phase will be changed, a second coherent beam B2 being used to holographically record the phase scrambled imaged on the plate 7. The plate 7 may then be placed in a store, and the transparency 5 desstroyed.

Referring now also to Fig. 2, in order to decode the phase scrambled image stored on the plate 7 it is necessary for an authorised person to be in possession of the optical phase encryption device 1, and also to have the knowledge of the relative displacements along the x and y directions of the plates 3. The plates 3 are arranged as in the recording stage, and a phase conjugate mirror 9, a coherent reconstructing beam B3, a beam splitter 11 and a mirror 13 being arranged such that the phase conjugate of the scrambled image stored on the plate 7 is shone through

the optical phase coding device 1 onto a screen 15. The image projected onto the screen will thus have the form of the original image carried on the transparency 5.

It will be appreciated that particularly where the system is used for archiving, it may be useful to reduce the size of the stored image. In such a case a telescopic arrangement may be used to reduce the size of the image passing through the encryption device 1 relative to the size of the transparency 5.

It will be seen that the above system has a high level of security, as even if an unauthorised person become in possession of the plates 3 constituting the optical phase encryption device, unless he knows the relative displacements of the plates both to the optical axis and to each other used to record the phase scrambled image he will be unable to reconstitute the input image. A lower degree of security may of course be achieved with only one phase plate 3. For example if this single plate had a phase retardation pattern recorded on it within 64 by 64 pixels, the input image being transmitted through a 32×32 pixel section of the plate, then displacement of the plate in units of one pixel in the x and y directions relative to the optical axis would allow a total of 32×32 combinations. Furthermore if the pattern of phase retardations across the plate has no rotational symmetry, rotation of the plate by ninety degrees about the optical axis multiplies the number of possible combinations by four.

It will be appreciated that four identical plates as in the particular system described above, the number of combinations is $(32 \times 32 \times 4)^4$, i.e. 2.8×10^{14}. The number of plates used, and thus the number of possible cominbations will of course be chosen to suit the level of security required in the particular application.

Turning now to Fig. 3, in the second system to be described, the information storage process is the same as in the first system, and thus the apparatus used is the same, corresponding components in the second system thus being correspondingly labelled to the first system. In order to avoid the necessity for a phase conjugate mirror however, the coherent reconstructing beam B4 is arranged to be the phase conjugate of the beam B2 used to record the scrambled image. This can readily be arranged where the beam B2 is a plane wave beam or a spherical wavefront beam.

It will be appreciated that many systems in accordance with the present invention are possible beyond those described in the above examples. In particular the phase plates need not be identical, although the use of identical plates has the advantage of manufacturing ease in that all the phase plates may then be reproduced from one master copy. Where it is not required that the phase plates be reproducible, a relatively cheap system in accordance with the invention may use one or more ground glass plates to produce the required phase scrambled image.

It will also be appreciated that whilst the use of a phase conjugate of the phase scrambled image enables the same plates to be used in the reconstruction of the image to those used in the storage process, by the use of appropriate "negatives" of the plates, it will not be necessary to form the phase conjugate of the phase scrambled image.

It will be appreciated that a system in accordance with the invention will have many applications, but will be particularly useful for the storage of information which is binary in intensity, for example text, as the wide dynamic range will improve the legibility of the reconstructed image. The system may also be used in secure communication systems where, for example an encrypted cine film is conveyed by a courier instead of an unencrypted film. Any number of subscribers may then view the film as long as the subscriber is in possession of the arrangement effective to reproduce the required unencrypted images, together with, in the case of an encryption device comprising a number of recordings of spatial patterns of phase variations to the relative displacements of the recordings.

CLAIMS

1. A secure storage system for the storage of information carried on a document comprising: means for directing light from an input image representative of the document through a first optical arrangement effective to produce a modified image across which there is a spatial pattern of phase variations relative to said input image; means for holographically recording the modified image; and means for subsequently directing light from the modified image through a second optical arrangement effective to reproduce the input image.

2. A system according to Claim 1 in which the second optical arrangement includes means for forming the phase conjugate of the modified image.

3. A system according to Claim 2 in which the second optical system includes the first optical system, light from the phase conjugate of the modified image being directed through the first optical arrangement.

4. A system according to any one of the preceding claims in which the first optical arrangement comprises at least one recording of a spatial pattern of phase variations.

5. A system according to Claim 4 in which the recording is a holographic recording.

6. A system according to any one of the preceding claims in which the input image is smaller than the corresponding area of the first optical arrangement such that the portion of the first optical arrangement through which light from the input image passes determines the form of the modified image.

7. A system according to Claim 4, 5 or 6 in which the first optical arrangement includes more than one recording arranged in series, the recordings being displaceable relative to each other in the directions normal to the direction of propagation of the light from the image, so as to vary the portions of the recordings through which light from the input image passes, and thereby vary the form of the modified image.

8. A secure storage system for the storage of information carried on a document, substantially as hereinbefore described with reference to the accompanying drawings.

9. A secure storage method for the storage of information carried on a document comprising; directing light from an input image representative of the document through a first optical arrangement effective to produce a modified image across which there is a spatial pattern of phase variations relative to said input image; holographically recording the modified image; and subsequently directing light from the modified image through a second optical arrangement effective to reproduce the input image.

10. A secure storage method for the storage of information carried on a document, substantially as hereinbefore described with reference to the accompanying drawings.

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